History and Recent Developments in Aluminum Smelting in China

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Abstract

In 2016, China produced 31.873 million tons of primary aluminum accounting for 54.1 % of global production. Following the first successful 600 kA potline in Weiqiao smelter at the end of 2014, another big Chinese aluminum producer, Xinfa smelter started three lines of 620 kA super-high amperage cells in 2015 and 2016. China is running rapidly and lonely on the road of primary aluminum production. This paper discussed the developments in aluminum smelting in China based on history of the Chinese aluminum industry, the research activities and engineering philosophy in aluminum electrolysis, and the giant demand for aluminum metal due to the rapid development in China's urbanization process.

Keywords: China; aluminum electrolysis; high amperage aluminum reduction cell.

1. Introduction

At the present time the electrolysis of cryolite-alumina molten salts, also known as Hall-Héroult process, is the only industrial process for the primary aluminum production. The temperature of electrolysis is usually in the range of 940 to 970 ^{o}C. The cathodic product is liquid aluminum and the anodic product is a mixture of CO and CO_2 gas. The energy consumption is about 13.500 kWh/kg Al.

In 2016, the global primary aluminum production was approximately 58.89 million tonnes. China produced 31.873 million tonnes accounting for 54.1 % of global production [1]. Currently, the largest prebake cell, operating at 620 kA, was started in China in 2015 [2]. Such great achievements were based on the development of fundamentals on aluminum electrolysis, including bath chemistry, cell magnetohydrodynamic (MHD) stability of the aluminum metal, energy balance and mass balance, electrode studies of very large anodes, materials selection and engineering.

In order to understand the rapid developments in aluminum smelting in China, we have to discuss the history of the Chinese aluminum industry, the research activities and engineering philosophy in aluminum electrolysis, and the giant demand for aluminum metal due to the rapid development in China's urbanization process.

2. The History of Chinese Aluminum Industry

The first Chinese aluminum smelter, Fushun Smelter went to production on 1st October, 1954 and produced totally 19 tons of primary aluminum in the remaining three months of 1954. The smelter had 144 45 kA Soderberg cells and was designed to produce 15 kt/a of aluminum. Fushun Smelter is the cradle of the Chinese Aluminum Industry, which not only produced aluminum but also exported engineers and technology to other new smelters. In 1974, a total of 22 aluminum smelters were producing aluminum with production capacity of 244 kt/a [3].

On 10 April 1975, the first 135 kA prebake anode cell with side breaking-feeding was started in Fushun Smelter. The cell was designed by Shenyang Aluminum and Magnesium Engineering & Research Institute (SAMI). The 135 kA prebake cell had 18 anodes operating at anode current density of 0.843 A/cm^2 and had two anode risers. The cell voltage was 4.0 - 4.1 V, and the current efficiency 90 % [4]. A group was assigned to study and measure the magnetic field of the pilot 135 kA cell. The group members came from Northeastern University (NEU), SAMI, Fushun Smelter and Zhengzhou Light Metals Research Institute (ZLMI). The group collected the necessary knowledge and data for developing prebake cells and trained experts for future development of 280 kA prebake cell several years later [5]. In November 1979, a total of 23, 135 kA side-by-side prebake cells were put into production in Fushun Smelter. Three of these cells were selected to test the center breaking-feeding, which was designed by Guiyang Aluminum and Magnesium Engineering and Research Institute (GAMI). The Chinese aluminum industry went into the era of prebake cell technology.

In December 1981, the first potline of 160 kA side-by-side prebake anode cell technology with center breaking-feeding was put into production in Guizhou Smelter. 160 kA cell technology was imported from Japan in 1979, and was widely adopted as the main cell technology for Chinese smelters in the next decade [3].

During 1986 to 1994, SAMI, GAMI, ZLMI, NEU, and Central South University (CSU) worked together to successfully develop the 280 kA prototype prebake cell technology in the Qinyang pilot smelter. It is considered as a milestone of the Chinese aluminum industry. From then on, the Chinese aluminum industry developed rapidly as shown in Figure 1 [1, 3, 6] and became the largest aluminum producer by country in the world in 2001.

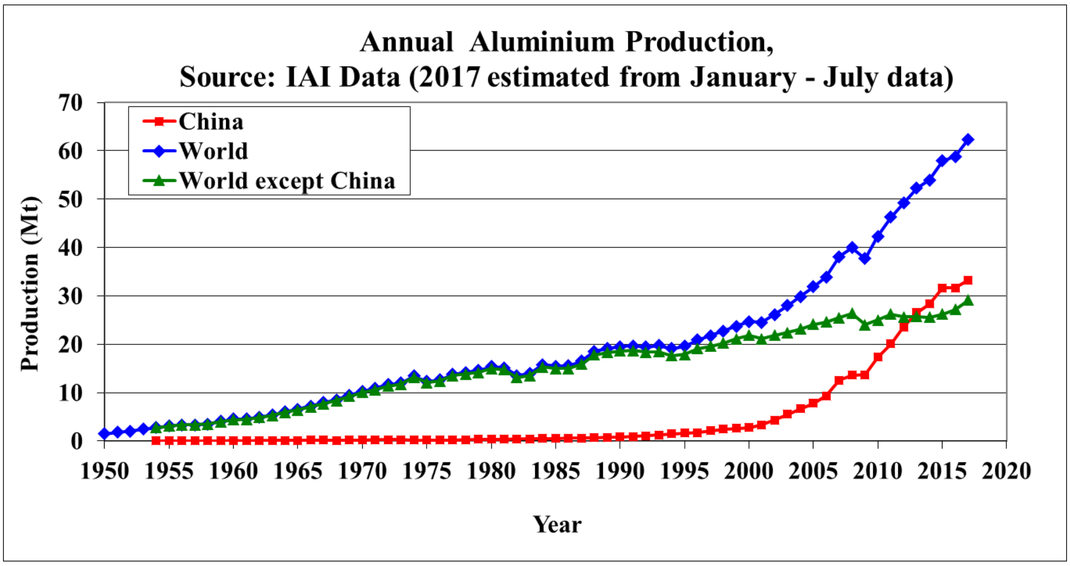

Figure 1. The historic aluminum production in China and the world from 1950 to 2016.

3. Development of Large High Amperage Cells in China

SAMI, GAMI, and Northeastern University Engineering and Research Institute Co. Ltd (NEUI) have been the three main designers for aluminum industries, including design of alumina refining plants and primary aluminum smelters during the last thirty years. SAMI and GAMI were two leading designing companies before the appearance of NEUI, which grew out of the Design Office of Northeast Institute of Technology (NEIT) founded in 1981 and was updated to Northeastern University Engineering and Research Institute in 1994. Northeastern University Engineering and Research Institute Co., Ltd. was registered in April 2004. NEUI designed 70 aluminum reduction potlines during the last 15 years, accounting for 30 % of Chinese aluminum production capacity [7] and 107 alumina plants accounting for 50 % of Chinese alumina production capacity.

As mentioned in the previous section, the Chinese aluminum prebake cell technologies were developed based on combination of self-development and inclusion of imported technology, especially 160 kA prebake cell technology from Japan. A precise historical agenda of Chinese high amperage aluminum prebake cell technology development is described as follows:

- 1986 - 1994, SAMI, GAMI and ZLMI made the successful development of 280 kA prototype pots in Qingyang pilot smelter [3].
- June 2002: The first SAMI SY300 kA potline was started in the Henan Longquan Aluminum Co. Ltd [8].
- August 2004: The first SAMI SY350 kA pot was started in the Henan Shenhuo Smelter.[8]
- August 2008: The first NEUI 400 kA potline with the capacity of 230 000 t/a was put into operation in Henan Zhongfu Industry Co. Ltd [9].
- April 2011: The first SAMI SY500 kA potline was put into operation in Liancheng aluminum smelter [10].

- August 2012: 12 SAMI SY600 kA pilot cells were started in Liancheng Smelter [2].
- December 2014: The first NEUI 600 kA potline with a capacity of 300 000 t/a was put into operation in the Weiqiao Smelter [2].
- November 2015: The first SY660 kA potline with a capacity of 350 000 t/a was put into operation in the Shandong Xinfa Smelter [2]. Two more potlines with these cells were started in 2016.

It took 23 years from the first 135 kA potline to the first 300 kA potline, but only 12 years from the first 300 kA potline to the first 600 kA potline. In this developing process of cell technologies, some new players, such as East Hope Group, Hongqiao Group, Xinfa Group, Shenhuo Group, Nanshan Group became the main driving forces for industrialization of new technologies. These groups are private companies full of spirit of risk, and are working efficiently and economically. Forty years ago, it took five years to build a smelter with capacity of 200 kt Al. Currently, some companies can finish a potline of 400 - 500 kA with capacity of 300 to 400 kt Al in four to six months.

The Chinese government encourages the aluminum producers to use advanced technology with higher energy efficiency, less pollution, and better working conditions for operators. In 2005, all Söderberg cells had to be stopped all over China. Currently, most cells are operated at amperage higher than 200 kA, as listed in Table 1 (placed at the end of the paper). 400 kA and higher amperage cells are the dominant technologies in Chinese smelters. As illustrated in Table 2, 400 kA prebake cell technology has better performance than 500 kA and 600 kA technologies. Yang Xiaodong, who is the chief engineer of SAMI, thinks that some fundamental rules for MHD, busbar design, and thermal balance are very different for 500 kA and above technologies compared to 400 kA technologies. With continuing study and retrofitting of these fundamental rules, the performance of super large cell technology will become better and better [11].

NEUI and SAMI are retrofitting and developing 600 kA+ prebake cell technology. Chinese investors are always interested in building new smelters with higher amperage cell technology because of its significant effect on decreasing investment per ton of aluminum. It would not be surprising that some larger cell technology might be put into operation in China in the near future.

Figure 2. Left picture: NEUI 600 kA prebake potline in Shandong Weiqiao aluminum

smelter; Right picture: SY620 prebaked potline in the Shandong Xinfa aluminum smelter.

Table 2. Key performance indicators (KPIs) of high amperage (≥ 400 kA) aluminum prebake cell technologies in China.

Cell technology	NEUI400(IV) [9]	SY400 [23]	SY500 [24]	SY600 [25]	NEUI600
Technology group	NEUI	SAMI	SAMI	SAMI	NEUI
Current (kA)	460	400	500	600	600
Production (t Al/cell-day)	3.48	3.01	3.70	4.56	4.56
Current Efficiency (%)	94	93.4	92	92.8	92.5
Cell voltage (V)	3.9	3.942	3.95	3.78	3.95
DC Energy Consumption (kWh/kg Al)	12.36	12.58	12.79	12.14	12.73

4. Development of New Techniques of Aluminum Electrolysis in China

As we know, the Hall-Heroult process is an energy intensive process with hazardous emissions, such as greenhouse gases, HF, SO_2, and some solid wastes. In 2016, total 7 % electricity of the country generated was consumed by Chinese aluminum electrolysis industry [1]. Chinese government supported big projects which are closely concentrated on energy saving and emissions reduction, the core issues of aluminum reduction technology. Considering the characteristic of aluminum reduction process including multi-physics fields coupling and multiple parameters association, effective research must be based on multidisciplinary association and systematic cooperation. We are trying our best to develop more advanced cell technology with high energy efficiency, safe emissions and intelligent control technology in aluminum industry to meet the targets for the national energy conservation and emission reduction. Some significant developments in Chinese aluminum smelting in the last decade are described below.

4.1 "Raised" NSC Cathode Blocks

In 2012 Professor Naixiang Feng of Northeastern University first reported that industrial tests of applying new uneven "novel structure cathode" (NSC) were successful in three 168 kA prebake cells at Chongqing Tiantai Aluminum Smelter in 2008, and in ninety-four 200 kA prebake cells of Huadong Aluminum Smelter in 2009, and in 350 kA cells of the Qingtongxia smelter. These industrial practices confirmed that the cells showed good performance with an average DC energy consumption of 12.043 kWh/kg Al. These test results were impressive as they indicate that more than 0.3 V could be saved on cell voltage together with a significant increase in current efficiency [12]. The NSC cells have been also used in high amperage cell technologies of 400 kA and above. In 2014, it was reported [13] that out of 17 667 high amperage cells in operation or construction, 599 cells (3.4 %) had non-flat cathodes.

Figure 3. Industrial aluminum electrolysis cells installed with the novel structure cathodes (NSC). Left picture: cathodes with "raised" transverse ridges; right picture: cathodes with "raised" small cylindrical columns.

Prof. Feng provided an effective way to improve cell stability by decreasing the velocity of metal flow and distortion of metal/bath interface. NSC technique was very effective for cells with poor MHD stability, such as early 200 kA to 300 kA cell technologies. With great improvement in physical fields design, MHD stability of 400 kA and above became better than early technologies. NSC technique is not attractive for new cell technologies any more.

4.2. Lower Energy Aluminum Reduction Cell

Currently, some researchers and engineers still argue about the effectiveness of Professor Feng's invention of novel structure cathode. The number of smelters still using this technology is smaller than five years ago. However, more and more smelters keep the strategy of controlling their cell voltage below 4.0 V even though the NSC technology was not adopted in their cells. Some other techniques and material selection were adopted to achieve the low cell voltage operation. These techniques are described as follows:

- Graphite or graphitic cathode block combined with better conductive collector bar connected to the cathode block by cast iron sealing. Compared to conventional cathode design in China, which is graphitic cathode block connected with collector bar by ramming paste sealing, the cathode voltage drop of industrial cells using the new technique decreases by 50 to 80 mV, according to industrial tests [11].
- New structure anode. Electronic resistance of the anode can be decreased by optimization of anode structure, such as anode stub, ingredients of cast iron, diameter of stub hole. New structure anode designed by SAMI (Figure 4) can decrease cell voltage by 30 mV compared to conventional anode, according to industrial tests [11].

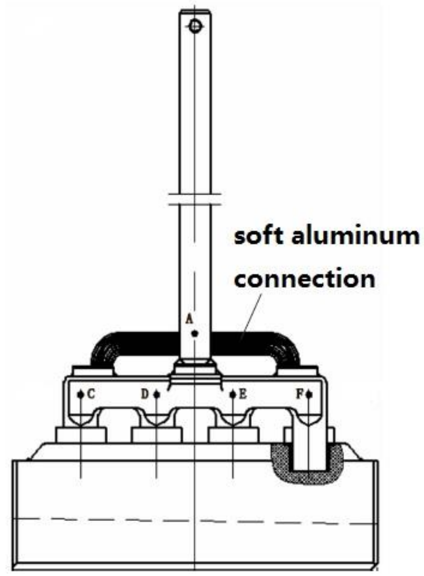

Figure 4. New structure anode.

- A new structure of cathode collector bar designed by SAMI (Figure 5) was used in industrial cells [14]. It could reduce horizontal current in the metal pad by 30 - 90 % and increase the cell stability according to simulation [11]. The industrial test on 220 kA cells confirmed that cells can be operated at 3.77 V with current efficiency of 91.84 % and energy consumption of 12.390 kWh/kg Al [11]. Another industrial test on SY300 cells confirmed that cells can be operated at 3.89 V with current efficiency 91.2 % compared with regular cells operated at 3.98 V with current efficiency 90.12 % [15]. However, some smelters reported early cathode failure due to application of this kind of cathode collector bar. According to SAMI's statistics, long term operational results of this technology have confirmed that the average service life of cells is more than 2000 days. Therefore, early cathode failure might not be caused by this technology. Another effect of slotted collector bars is an increase of cathode voltage drop which was calculated to be as much as 53 mV for a specific slot design modelled [16]. SAMI solved the problem by increasing the cross-section area of the collector bar. The typical size of cross-section of the new collect bar is 100×230 mm, which has larger cross-section area than old design of 65×180 mm or 65×240 mm.

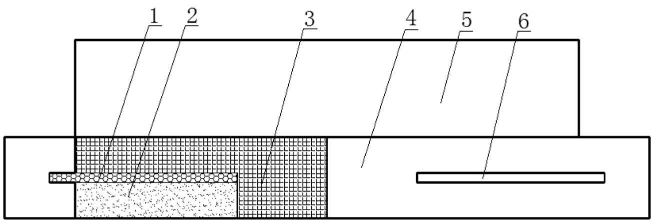

Figure 5. New structure of collector bar of cathode [14] -: 1 — Insulating materials of the slots; 2 — Insulation on collector bar sides; 3 — Conductor; 4 — Cathode collector bar; 5 — Cathode carbon block; 6 — Slot.

4.3. New Methods for Spent Potlining (SPL) Disposal

China has the largest aluminum production capacity in the world and thus it also has the largest amount of waste from failed cathodes. Using an approximate estimate of 35 kg/t Al of SPL generation in Chinese smelters, 1.11 million tonnes of SPL generated in China in 2016 alone. SPL contains compounds that are toxic, hazardous, or environmentally undesirable. So, it is becoming one of the aluminum industry's major environmental concerns.

- In 2015, Professor Feng Naixiang invented a new method for treatment and recycling of spent potlining [17]. Spent carbon materials, including spent potlining and carbon dust, are heated in a vacuum furnace at 1000 to 1400 ^{o}C. The volatile materials including sodium metal and fluorides are then separated from the carbon. Because of the melting point difference, sodium metal will be solidified at temperatures below 500 ^{o}C, and the electrolyte in the range of temperatures 500 - 1000 ^{o}C in the upper part of the vacuum chamber. After such treatment, the purity of carbon can reach up to 92 % and higher. The new method can also be used to recycle the spent insulating materials by addition of aluminum dust from the foundry shop. Aluminum reacts with sodium oxide to produce metallic sodium. During the step of distillation cryolite-based electrolyte and metallic sodium are removed from the insulating materials, which can be used again in prebake cells. A pilot plant based on the vacuum process with capacity of 1500 tons/year is under construction in Guangxi province.
- In 2017, a treatment line of SPL based on Chalco-SPL process [18] was put into operation successfully; it has treatment capacity of 10 000 tons per year and produces raw materials for cement manufacture.

4.4. Aluminum Electrolysis Using Wind Power

China is rich in wind resources because of its long monsoon period. There are two main areas with rich wind resources in China (Figure 6): (1) Northern areas (Xinjiang province and Inner Mongolia province) with wind energy densities reaching 200 - 300 W/m^2 and 5000 - 7000 usable hours per year; (2) Coastal areas and islands with wind power densities above 500 W/m^2 and 7000 - 8000 usable hours per year. The wind power industry increased rapidly and reached 105 GW of electricity generating capacity installed in China in 2015 [19].

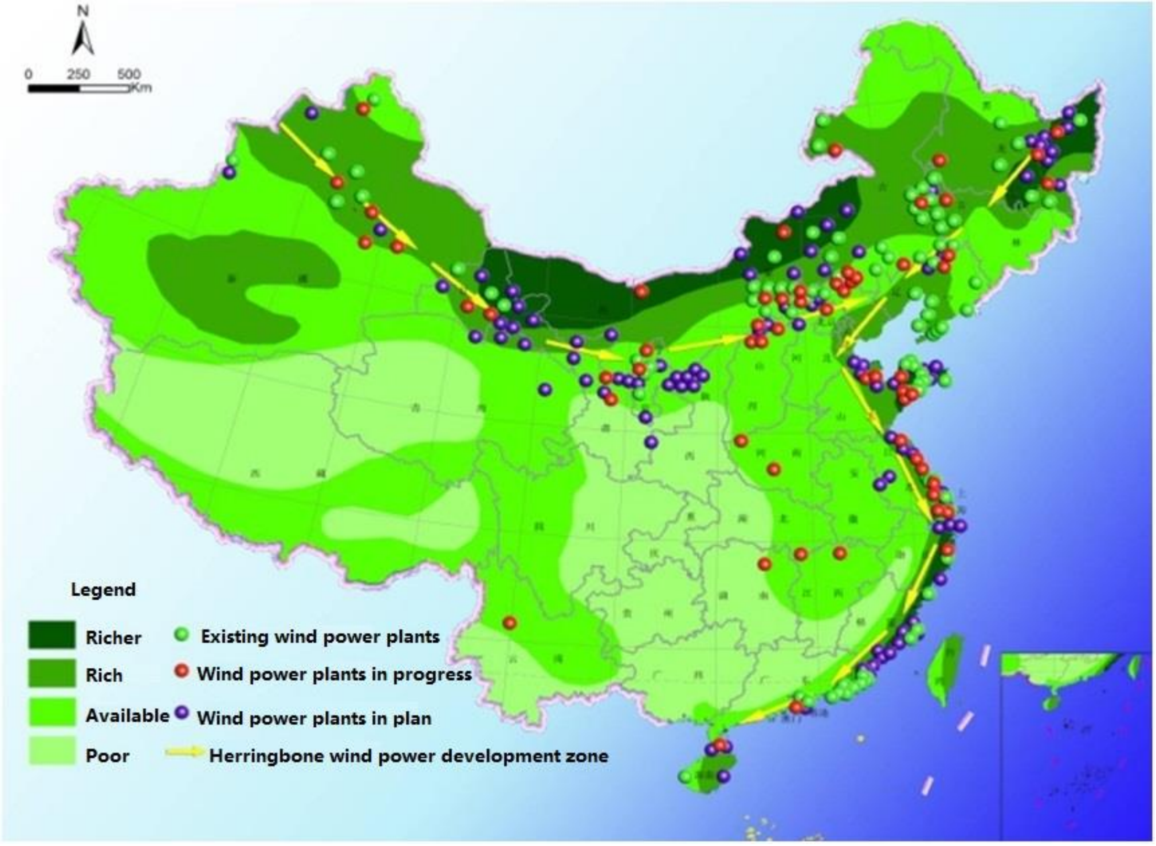

Figure 6. Distribution of wind mills in China.

Prof. Wang Zhaowen has proposed that aluminum electrolysis can be used as a special load for non-grid connecting wind power. A new type of aluminum electrolysis cell was designed and installed in NEU, which has higher tolerance for power fluctuation. The test cell with sidewall heat recovery system is shown in Figure 7. Hitec salt is used as heat exchange medium in this cell. When cells receive a higher energy input, more heat can be taken out to keep the sidewall ledge stable. This can be realized easily by tuning the flow rate of Hitec salt. In China, aluminum smelters are always built together with an alumina refining plants. Therefore, the heat from the cells can be transferred to the alumina plant and used for the bauxite digestion.

A 3 kA laboratory scale test was carried out in NEU. The results showed that the temperature of the Hitec salt out from the heat exchanger can reach up to 400 ^{o}C. A thermo-electric model of aluminum reduction cell using non-grid connecting wind power was built using ANSYS. The impact of the flow rate of the Hitec salt on heat balance and ledge thickness was studied. The results showed that through control of the flow rate of the Hitec salt they were capable of adjusting cell heat balance easily and effectively. With the aid of mathematical simulation, Professor Wang thinks that the new cell can operate normally with variable current with a variation range of ± 20 %.

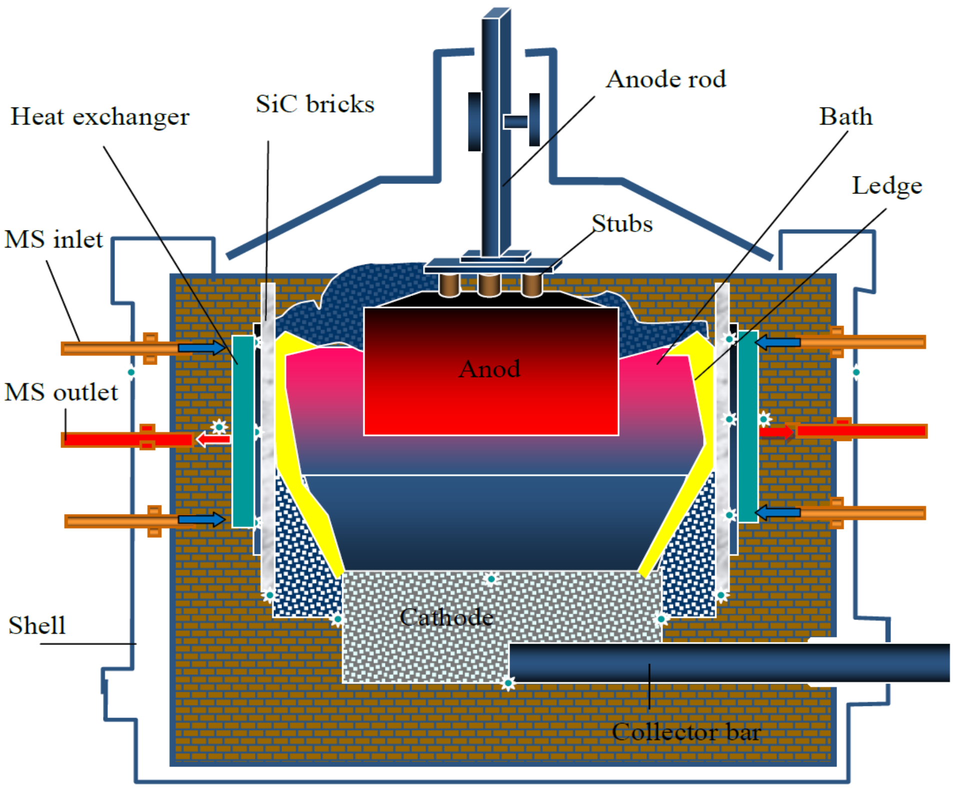

Figure 7. 3 kA aluminum electrolysis cell with sidewall heat recovery system.

5. China Needs Aluminum Metal

After forty years development, China's urbanization rate (defined as the percentage of the total population living in urban areas) is 55.6 % [20], at an average increasing rate of 1 % per year since 1978. According to Wang's prediction, urbanization rate will hit 66 % in 2030, and 100 to 150 more megacities will form in China in the next decade [21]. As we know, urbanization process certainly increases the aluminum consumption. The urbanization process of the USA confirmed that the average aluminum consumption reached saturation when the urbanization rate of the USA reached 75 %. Therefore, China's aluminum consumption will continue to increase at a rate of 4 – 5 % per year in the next decade even though its present annual consumption has reached 34.087 Mt [22].

6. Conclusions

We must thank many pioneers for their great works in establishing the Chinese aluminum industry and moving it forward. The most eminent members are Zhuxian Qiu of Northeastern University, Yexiang Liu of Central South University, Ruixiang Yang of SAMI, and Shihuan Yao of GAMI. The younger scientists and engineers are working hard with great passion to make the Chinese aluminum industry better and better.

Chinese smelters will continue to practice and develop advanced technology for the sake of enhancing their competition in the world. Aluminum smelters controlled by private enterprise will play more and more important role in the next decade.

Chinese people will consume giant amount of aluminum metal to improve their quality of living and make the world better.

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Table 1. List of the Chinese aluminum smelters.

	Corporation	Location	Company name	Nameplate capacity (tpy)	Cell technology
1	China Hongqiao Group	Zhouping, Shandong	Shandong Weiqiao Aluminum Smelter	6400 000*	600 kA, 500 kA, 400 kA (NEUI)
2	Aluminum Corporation of China Limited (CHALCO)	Baotou, Inner Mongolia	Baotou Aluminum Factory	1 350 000*	400 kA, 200 kA, 240 kA, 500 kA (SAMI)
		Yongdeng, Gansu	Liancheng Aluminum Plant	520 000	200 kA, 500 kA (SAMI)
		Lanzhou, Gansu	Lanzhou Aluminum Smelter	430 000	200 kA, 400 kA
		Hejin, Shanxi	Huaze Aluminum	420 000	240 kA (GAMI)

			Industries		
		Linyi, Shandong	Huayu Aluminum Works	200 000	240 kA (GAMI)
		Xining, Qinghai	Qinghai Aluminum Plant	400 000	180 kA, 200 kA, 160 kA (SAMI)
		Jiaozuo, He'nan	Jiaozuowanfang Aluminum Co. Ltd.	440 000	440 kA (SAMI)
		Guiyang, Guizhou	Guizhou Aluminum Plant	280 000	Move to a new place
		Zunyi Xian, Guizhou	Zunyi Aluminum Works	260 000	350 kA (GAMI)
3	Xinfa Group	Chiping, Shangdong	Shandong Chiping Xinfa Aluminum Co.	1500 000*	240 kA, 620 kA (SAMI)
		Fukang, Xinjiang	Nongliushi Smelter Xinjiang	1 900 000	500 kA, (SAMI)
		Jingxi Xian, Guangxi	Guangxi Xinfa Aluminum	320 000	240 kA (SAMI)
4	East Hope Group	Baotou, Inner Mongolia	Baotou Oriental Hope Aluminum Co	860 000	320 kA, 450 kA (SAMI)
		Jiamusae, Xinjiang	Xinjiang Easthope Coal Power & Aluminum	800 000*	500 kA (SAMI)
5	State Power Investment Corporation (SPIC)	Qingtongxia Shi, Ningxia	Qingtongxia Aluminum Co., Ltd.	420 000	200 kA, 350 kA (GAMI)
		Yingchuan Shi, Ningxia	Qingtongxia Aluminum Co., Ltd.	570 000	350 kA, 400 kA (SAMI)
		Tongliao, Inner Mongolia	Tongliao Aluminum Co	173 000	110 kA(SAMI); 240 kA (GAMI)
		Houlinghe, Inner Mongolia	Huomei Hongjun Aluminum Smelter	670 000	300 kA, 350 kA, 400 kA (SAMI)
		Xining City, Qinghai	Huanghe Xinye Aluminum Smelter	600 000	350 kA, 400 kA (SAMI)
6	Hangzhou Jinjiang Group	Huolinghe, Innermogolia	Neimeng Jinlian Aluminum	1600 000*	400 kA (NEUI); 500 kA (SAMI)
		Zhongning, Ningxia	Jongning Aluminum Smelter	300 000	400 kA (NEUI)
7	Gansu Jiu Steel Group	Jiayuguan, Gasu	Gansu Dongxing Smelter	1 359 000	400 kA, 500 kA (SAMI)
		Longxi,Gansu	Gansu Longxi Dongxing Smelter	250 000	240 kA (SAMI)
8	Shenhuo Group	Yongcheng, He'nan	He'nan Qinyang Aluminum Power	450 000	350 kA, 400 kA (SAMI)
		Jiamusaer,	Xinjiang Shenhuo	820 000	400 kA, 500 kA

		Xinjiang	Aluminium		(SAMI)
9	Shanxi Non-Ferrous Co. Ltd	Tongchuan, Shanxi	Shanxi Tongchuan Aluminum Co, Ltd	600 000	600 kA (SAMI); 240 kA (GAMI)
		Yulin, Shanxi	Shanxi Non-Ferrous Yulin Smelter	630 000	400 kA (SAMI)
10	Yunnan Aluminum Group	Yangzonghai, Yunnan	Yunnan Aluminum Co. Ltd	300 000	300 kA (GAMI)
		Jianshui Xian, Yunnan	Yunnan Yongxin Aluminum	300 000	300 kA (GAMI)
		Fuyuan Xian Yunnan	Yunnan Zexin Aluminum	250 000	420 kA (GAMI)
		Yunnan Gejiu	Yunnan Runxin Aluminum	300 000	300 kA (GAMI)
11	Zengshi Group	Shihezi, Xinjiang	Tianshan Aluminum Co.	1 100 000	400 kA (NEUI)
12	Qinghai Provincial Investment Group Co. Ltd	Datong Xian, Qinghai	Qinghai Qiaotou Aluminum & Power Co., Ltd.	300 000	240 kA (GAMI)
		Minhe Xian, Qinghai	Qinghai Western Hydro Power Co. Ltd	450 000	240 kA (GAMI)
		Xining, Qinghai	Qinghai Western Minerals Baihe Aluminum Co, Ltd	100 000	240 kA (GAMI)
		Xining, Qinghai	Qinghai Wuchan Industry Investment Co. Ltd	100 000	240 kA (GAMI)
13	Sichuan Qiya Aluminum Group	Jiamusaer, Xinjiang	Xinjiang Qiya Energy Aluminum Electric Co. Ltd	880 000	530 kA (CSUI**)
14	Xinheng Group	Xining, Qinghai	Qinghai Xinheng Hydro Power Development Co. Ltd	350 000	400 kA (SAMI)
		Xining, Qinghai	Qinghai Huanghe Hydro Power Recycling Aluminum Co. Ltd	500 000	300 kA (GAMI)
15	He'nan Yulian Power Group.	Gongyi, He'nan	Zhongfu Industry Group	500 000	320 kA (GAMI), 400 kA (NEUI)
		Linzhou, He'nan	Lifeng Aluminum Co. Ltd.	350 000	400 kA (NEUI)
16	Nanshan Group	Yantai, Shandong	Nanshan Aluminum Co., Ltd.	840 000	171 kA (SAMI); 300 kA, 400 kA (NEUI)

17	Henan Xin’an Power Group	Luoyang, He'nan	He'nan Wanji Aluminum Co. Ltd.	500 000	300 kA, 400 kA (SAMI)
18	Guangxi Investment Group	Laibin Yinhai	Laibin Yinhai Aluminum Company	250 000	330 kA，400 kA (GAMI)
		Baise, Guangxi	Guangxi Baise Xinghe Smelter	200 000	240 kA (GAMI)
19	Xinjiang Jiarun Group	Manasi, Xinjiang	Xinjiang Jiarun Aluminum Co. Ltd	400 000	500 kA (SAMI)
20	Yunnan Dongyuan Coal Group	Qujing, Yunnan	Yunnan Dongyuan Qujing Aluminum Co. Ltd	380 000	230 kA (GAMI)
21	Guangxi Baise Mining Group	Baise, Guangxi	Gauangxi Baise Mining Aluminum Co. Ltd	300 000	400 kA (GAMI)
22	Bosai Group	Aba, Sichuan	Sichuan Aba Aluminum Smelter	200 000	360 kA
		Meishan Qimingxing	Bomei Aostar Aluminum Co. Ltd	125 000	350 kA (GAMI)
23	Chongqing Energy Investment Group	Chongqing	Chongqing Qi’neng Power &Aluminum Co. Ltd	330 000	420 kA (GAMI)
24	Shanxian Hengkang Aluminum Co. Ltd	Shanxian, He'nan	Shanxian Hengkang Smelter	240 000	400 kA (SAMI)
25	Shanxi Yangquan Coal Group	Yangquan, Shanxi	Shanxi Yangquan Aluminium smelter.	220 000	300 kA, 240 kA (GAMI)
26	Datang International	Inner Mongolia Datang	Inner Mongolia Datang International Aluminum	163 000	400 kA (NEUI)
27	Xinjiang Tianlong Mineral Co.	Fukang, Xinjiang	Tianlong Aluminum Smelter	150 000	200 kA, 400 kA (SAMI)
28	Guangyuan Aostar Aluminum Co. Ltd	Guangyuan Sichuan	Guangyuan Aostar Aluminum smelter	114 000	200 kA (GAMI)
29	Guangxi Denggao Group	Xingrenxian Guizhou	Guizhou Denggao Aluminum Plant	100 000	420 kA (GAMI)
30	Chongqing Guofeng Industry Co. Ltd	Chongqing	Chongqing Guofeng Industry smelter	100 000	240 kA (GAMI)
31	Fujian Nanping Aluminum Co. Ltd	Nanping, Fujian	Fujian Nanping Aluminum smelter	100 000	240 kA (GAMI)
32	Xinjiang Zhonghe Group	Fukang, Xinjiang	Zhonghe Group	80 000	500 kA (SAMI) 400 kA (NEUI)
33		Chongqing	Chongqing Jinghongyuan Industry Co. Ltd	60 000	400 kA (GAMI)

34	Chongqing Helong Industry Group	Chongqing	Chongqing Dongsheng Aluminum Co. Ltd	52 000	200 kA (GAMI)

*Some data are estimated;

**CSUI: Central South University Institute Co. Ltd.